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RESEARCH ARTICLE

Software to Compute Pile Load Capacity in Case of Variable Soil Stratification.

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Abstract

High degree of uncertainty is associated with the geotechnical investigations as it is impossible to conduct the pile load test on each and every pile due to their expensiveness and tedious nature. As per the guidelines given by the IS 2911 (part1-section 2)-2014 considers only the granular or clayey (C or Φ soils) throughout the depth of the pile. This is not actually possible in the actual field. So it is necessary to build the software which can calculate the pile load capacity for foundation soil having different soil strata, existing throughout the entire depth of pile. This software will eliminate excessive cost of investigations. **We have derived a new formula based on the existing formula given in the IS code 2911 and this formula is used for computation of result in the software.**

Introduction:-

Geotechnical engineering is sub-branch of civil engineering discipline that deals with the engineering behaviour of earthen materials. Geotechnical engineering also has uses and application in mining, military, petroleum and different engineering discipline. It uses the basic principles soil mechanics to investigate surface and subsurface conditions and materials. It also deals with stability of slopes, soil deposits earthwork design and foundation design.
One of major geological problem of the earth's subsurface topography lies in the fact that the soil below the ground does not have uniform soil stratification. For a given smallest area of land one cannot say that the soil type and properties of the soil in this small area are uniform. These soil properties may change laterally (horizontally) as well as vertically (in depth). Soil stratification may change in type of soil, properties of soil, shear strength parameters, soil structure, permeability and porosity etc. It is therefore necessary to determine accurate soil stratification by use of modern paraphernalia which gives accurate results. The soil beneath plays a major role in the design of foundation and also the design of subsequent structure.

Accurate soil tests, results in increased life of structures, eliminating need of maintenance, if any. Geotechnical investigation only cost 1-2% of the total cost of the project but proves to be crucial.

Soil stratification is helpful in knowing the Pile Load Capacity (PLC) in case of variable soil stratification. PLC is the maximum amount of load a pile foundation can carry before failure.
In this project attempts have been made to accurately examine PLC in case of variable soil stratification with the use of the software/excel sheet.

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Literature review:-

- Narayan V Nayak mentions in his book "Foundation Design manual" page number 1.81

"In a very stiff to hard clayey soils, particularly with N values of standard penetration test greater than 30, reliability of laboratory tests conducted on so called undisturbed samples is very low. In such cases dependence shall be on penetration test and/or pressuremeter tests."
This software does not require N value or SPT value as inputs. In such a case we will not input "N" value and it will be evident from the software that the software will not show the same "N" value as derived from the test.
As the "N" value is not required as main input for the software, no computation of the software data will be based on the requirement of the "N" value and the results will be accurate.

- Further adding to the above contents Gopal Ranjan in his book "Basic and Applied Soil Mechanics" page number 589 wrote,

"Correlation of N value and soil parameters is available mainly for cohesionless soils. The use of N values for cohesive soils is limited, since the compressibility such soil is not reflected by N value"
Also P V Varghese mentioned that
"Even though are not considered as good measure of the strength of clays, it is used extensively as a measure of the consistency of clays. The consistency is then related to its approximate strength," in his book Foundation Engineering page 16.

Interpretation of pile load test result:-

The interpretation of results PLT plays a crucial role in deciding the failure capacity of the given pile. Also the interpretation of the PLT load test results in finding out the maximum possible load a pile can take.

This computation is very complex problem requiring very careful consideration of factors like soil profile, pile installation method, sensitivity of the structure, possibility of negative drag etc.

Fellenius in the year 1975 described eight methods of pile failure and also with examples of full scale field test showed that the interpreted smallest and largest value differed by atleast 40%.

Chin Fung Kee in the year 1977 suggested a plot of settlement per unit load as abscissa against settlement as ordinate to determine the ultimate capacity of a test pile, assuming the load- settlement relationship is hyperbolic.

Some of the well-known fundamentals of the failure load are given below:-

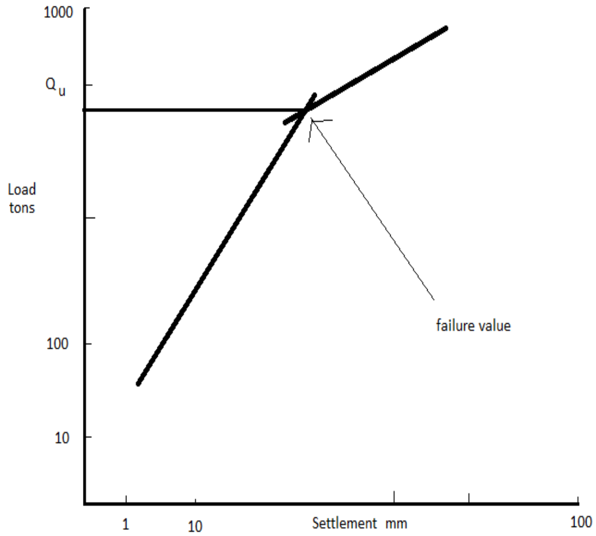


Fig 2.1 LOAD V/S SETTLEMENT GRAPH

1.)De Beer in the year 1968 plotted the load settlement values in a log-log scale, where the values can be shown to fall on two straight lines. The intersection of the lines corresponds to the failure value of that pile.
In this the interpreted analysed values is conservative and the corresponding pile settlement is also small.

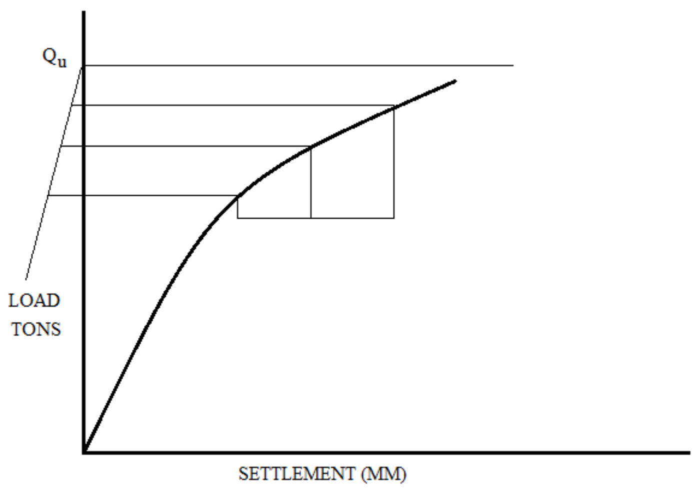


Fig 2.2 LOAD V/S SETTLEMENT GRAPH

2.)Mazirkiewicz in the year 1972 proposed a method that allows the failure load to be extended even if the maximum load is smaller than the failure load.

The figure shows equal settlement lines are drawn corresponding to the load. From the junction of each load line with the load axis a 45^0 line is drawn to intersect the next load line which intersects the next load line. It is based on the assumption that load-settlement curve is parabolic.

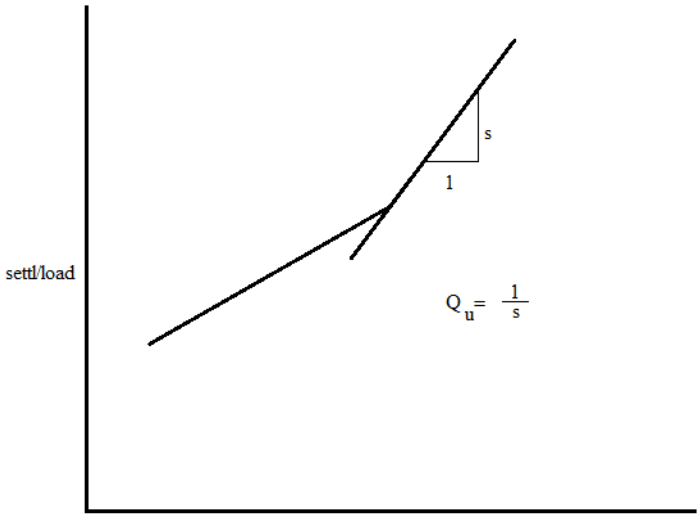


Fig 2.3 LOAD V/S SETTLEMENT GRAPH

3.)Chin Fung Kee in the year 1977 suggest a graph of the settlement is divided by load versus settlement. The graph consist of 2 straight lines. During the initial loads, the ratio of settlement to load is almost constant and as pile approaches failure, the graph shows the straight line with steeper slope.
The inverse of the slope for the second straight line indicates failure corresponding to the load value of the curve.

Problem deifinition:-

1.1 Problem Justification:-

For construction of any type of building it is necessary to determine various soil parameters. These parameters includes shear strength parameters, soil stratification, SBC etc. To determine the SBC of soil it is necessary to carry out Pile Load Test (PLT). Pile load capacity test is very expensive and cannot be performed at a very large number of stations and one pile load test can take about a month to get results. As it cannot be performed at many places accurate results cannot be obtained. By the use of the software of the software we made we can accurately or near to accurate results can be obtained.
The software is open source and is user friendly which a normal person can use. It doesn't require any specialised training for operation. Any soil stratification can be computed with the use of this software on the basis of the different soils.

There are approximate 5% piles that are tested for the design of the foundation. That means there are 2-5 piles which are tested and approximately 95% are remained untested. This give high percentage of uncertainty in the design. So it is therefore necessary to test all the piles at failure to get accurate design parameters.

If you look at any international codes as well Indian standard code, engineering designs are not 100% correct because of the assumptions made in the results. So use of software decreases this uncertainty and gives the best design conditions.

Aim of the project:-

The aim of the study is to develop a software that can directly compute the pile load capacity upon the input of the certain parameters.

Objectives of the project:-

- To find pile load capacity in terms of variable soil stratification.
- To eliminate the need of performing too many pile load test on the sub surface.
- To further reduce the cost of geotechnical investigation.
- To provide free, user friendly and completely robust software to geotechnical engineers for the betterment of the infrastructure.

About software:-

Actually in the field, hardly pure cohesive soil or purely granular soil is available. Hence in this software an approach is made to derive the pile capacity for C-Φ soil. Many professional softwares are available to derive pile capacity for C-Φ soil. (like GEO 5, All-pile, L-pile etc)
But the professional software are having many limitations like
1) They are not user friendly
2) They are very costly (in terms of lacs of rupees)
3) They do not automatically accept changes of revised codal provisions.
4) They do not provide detail calculation as per our requirement

About our software:-
The software is totally
1) User friendly and
2) Maintenance free

Design for use, reuse and sustainability:-
(I) Design for use:-
The software designed is ready to use if required data are available like
1) Diameter of pile
2) Length of pile
3) Shear parameters of soil (cohesion and angle of internal friction)
4) Unit weight of soil etc.
These data can be obtained from the traditional soil tests.

(II) Design for reuse
The software can be reused for n number of times, for different diameter, different length and different soil parameters.

(III) Design for sustainability
The software is sustainable for n number of years provided that necessary updates are incorporated time to time.

(IV)Prototyping
It is not applicable for software. But a prototype modeling of a pile load test can be prepared to check the pile load capacity calculated from software.

(V) Test the prototype
The prototype is made showing following components
1) Soil strata
2) Pile
3) Loading arrangement

(VI) Measuring instruments
Visual observation can be made that - as the load on pile increases, the settlement of pile also increases.

(VII) Comparison of existing methods
In IS 2911, method for calculation of pile capacity is given for pure granular soil and pure cohesive soil only. But in actual field conditions, the soil is hardly pure granular or pure cohesive in nature. Hence this software is prepared in excel to determine the capacity of pile for actual field conditions having mix nature of soil (granular+cohesive)
Few readymade softwares are available to calculate pile capacity for mix soil conditions, but they are very costly and not user friendly. This software is user friendly, transparent and updatable.

Derivation of the formula:-

To derive the capacity of pile, Guidelines are given in IS 2911 (Part 1 section 2) -2014 . In this code equations are given to determine ultimate capacity of pile in soil in Clause B-1 and Clause B-2
The equations are given for

1) Piles in Granular soils (Φ soil) and
2) Piles in Cohesive soils (C soil)

Limitations of the IS code:-
1 IS code 2911 assumes that same type of soil i.e pure cohesive or pure granular soil is found through-out the depth of excavation. But in real practice this case does not come into practicality.
2 IS code 2911 does not consider the change in soil stratification.
The formulas given in the IS code are:-

B-1 PILES IN GRANULAR SOILS

The ultimate load capacity (Q_u) of piles, in kN, in granular soils is given by the following formula:

$$Q_u = A_p(\tfrac{1}{2} D\gamma N_\gamma + P_D N_q) + \sum_{i=1}^{n} K_i P_{Di} \tan\delta_i A_{si} \quad \ldots (1)$$

The first term gives end-bearing resistance and the second term gives skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2;

D = diameter of pile shaft, in m;

γ = effective unit weight of the soil at pile tip, in kN/m^3;

N_γ and N_q = bearing capacity factors depending upon the angle of internal friction, ϕ at pile tip;

P_D = effective overburden pressure at pile tip, in kN/m^2 (*see* Note 5);

$\sum_{i=1}^{n}$ = summation for layers 1 to n in which pile is installed and which contribute to positive skin friction;

K_i = coefficient of earth pressure applicable for the ith layer (*see* Note 3);

B-2 PILES IN COHESIVE SOILS

The ultimate load capacity (Q_u) of piles, in kN, in cohesive soils is given by the following formula:

$$Q_u = A_p N_c c_p + \sum_{i=1}^{n} \alpha_i c_i A_{si} \qquad \ldots(2)$$

The first term gives the end-bearing resistance and the second term gives the skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2;

N_c = bearing capacity factor, may be taken as 9;

c_p = average cohesion at pile tip, in kN/m^2;

$\sum_{i=1}^{n}$ = summation for layers 1 to n in which the pile is installed and which contribute to positive skin friction;

α_i = adhesion factor for the ith layer depending on the consistency of soil, (*see* Note);

c_i = average cohesion for the ith layer, in kN/m^2; and

A_{si} = surface area of pile shaft in the ith layer, in m^2.

The formulas that are given in the IS code are manipulated to get the formula that is used in the software.

The friction components of both the formulas are merged and end bearing components of both the formula are combined. This gives rise to the new formula.

The total friction component of the pile is given by **new formula.**

Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan d x As] + [a x C x A_s] [Granular soil + Cohesive soil]

The total end bearing component of the pile is given by **new formula.**

Ultimate end bearing capacity (Qu)b = [Ap(1/2 D x g x Ng + Pd x Nq)] + [Ap x Nc x Cp] [Granular soil + Cohesive soil]

Analysis and result:-

General:-

To analyze the data we will first conduct the PLT on the actual site to obtain the soil sample. This soil sample will be taken to laboratory for further testing of the of the soil sample. Shear strength parameters (cohesion and angle of internal friction) of the soil sample are found out.

Testing of soil:-

Having collected the soil sample, the specimen is taken to the laboratory for further testing of the soil sample. Soil sample is tested for the shear strength parameters. We have collected the data from 5 different sites, whose shear strength parameters are as follows:-

Location 1:-

Frictional capacity of pile

Layer 1			
		Location	Vasad
	D	Stem dia , cm	45
	L	Length of pile L1, cm	200
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0019
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.9
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	21

Layer 2			
	D	Stem dia , cm	45
	L	Length of pile L2, cm	350
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0019
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.3
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	19

Layer 3			
	D	Stem dia , cm	45
	L	Length of pile L3, cm	425
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0019
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.3
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	23

End bearing capacity of pile

D	Pile Dia in cms	45
□	Effective unit weight of soil at pile tip in kg/cm^3	0.0021
Ø	Angle of internal friction around pile tip in degree	23
C_p	Average cohesion at pile tip,kg/cm^2	0.3

Location 2

Frictional capacity of pile

Layer 1			
		Location	Surat
	D	Stem dia , cm	60
	L	Length of pile L1, cm	100
	K	Coefficient of earth pressure	0
	□	Unit weight in kg/cm^3	0.0018
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.4
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	12
Layer 2			
	D	Stem dia , cm	60
	L	Length of pile L2, cm	400
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.00185
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.32
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	19
Layer 3			
	D	Stem dia , cm	60
	L	Length of pile L3, cm	350
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0019
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.36
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	24

End bearing capacity of pile

D	Pile Dia in cms	60
□	Effective unit weight of soil at pile tip in kg/cm^3	0.0021
Ø	Angle of internal friction around pile tip in degree	24
C_p	Average cohesion at pile tip,kg/cm^2	0.36

Location3

Frictional capacity of pile

Layer 1			
		Location	Bharuch
	D	Stem dia , cm	75
	L	Length of pile L1, cm	250
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0018
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.36
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	10
Layer 2			
	D	Stem dia , cm	75
	L	Length of pile L2, cm	400
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.00183
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.33
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	15

Layer 3			
	D	Stem dia , cm	75
	L	Length of pile L3, cm	350
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0020
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.35
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	20

End bearing capacity of pile

D	Pile Dia in cms	75
□	Effective unit weight of soil at pile tip in kg/cm^3	0.0022
Ø	Angle of internal friction around pile tip in degree	20
C_p	Average cohesion at pile tip,kg/cm^2	0.35

Location 4

Frictional capacity of pile

Layer 1			
		Location	Dahej
	D	Stem dia , cm	90
	L	Length of pile L1, cm	440
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0018
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0.36
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	0
Layer 2			
	D	Stem dia , cm	90
	L	Length of pile L2, cm	360
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.00183
	α	Reduction factor	0.6
	C	Average cohesion ,kg/cm^2	0.81
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	0
Layer 3			
	D	Stem dia , cm	90
	L	Length of pile L3, cm	600
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0020
	α	Reduction factor	0.4
	C	Average cohesion ,kg/cm^2	1.1
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	0

End bearing capacity of pile

D	Pile Dia in cms	90
□	Effective unit weight of soil at pile tip in kg/cm^3	0.0022
Ø	Angle of internal friction around pile tip in degree	0
C_p	Average cohesion at pile tip,kg/cm^2	1.1

Location 5

Frictional capacity of pile

Layer 1			
		Location	Rajasthan

	D	Stem dia , cm	75
	L	Length of pile L1, cm	250
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0018
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	21
Layer 2			
	D	Stem dia , cm	75
	L	Length of pile L2, cm	480
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.00183
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	25
Layer 3			
	D	Stem dia , cm	75
	L	Length of pile L3, cm	500
	K	Coefficient of earth pressure	1.0
	□	Unit weight in kg/cm^3	0.0020
	α	Reduction factor	1.0
	C	Average cohesion ,kg/cm^2	0
	□ □ □ □ □	Angle of wall friction between pile and soil, degree	32

End bearing capacity of pile

D	Pile Dia in cms	75
□	Effective unit weight of soil at pile tip in kg/cm^3	0.0022
Ø	Angle of internal friction around pile tip in degree	32
C_p	Average cohesion at pile tip,kg/cm^2	0

SOFTWARE COMPUTED DATA

The data and soil test results are input for the software to work. These data inputted will compute the pile capacity based on the formula we have derived. The software computed results are as shown below:-

LOCATION 1

Layer 1				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Vasad
1	D	Stem dia , cm	Given	45
2	L	Length of pile L1, cm	Given	200
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	1590
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	0.38
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.19
6	□	Unit weight in kg/cm^3	Given	0.0019
7	A	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.9
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	21
1	As	Surface area of pile shaft in cm^2	As = π D L	28274

0				
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	27.51
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	11.0
Layer 2				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Vasad
1	D	Stem dia , cm	Given	45
2	L	Length of pile L2, cm	Given	350
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	1590
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.38
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	1.05
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.71
6	□	Unit weight in kg/cm^3	Given	0.0019
7	A	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.3
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	19
10	As	Surface area of pile shaft in cm^2	As = π D L	49480
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	26.98
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	10.8
Layer 3				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Vasad
1	D	Stem dia , cm	Given	45
2	L	Length of pile L3, cm	Given	425
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	1590
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	1.05
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	1.85
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	1.45
6	□	Unit weight in kg/cm^3	Given	0.0019
7	A	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.3
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	23
10	As	Surface area of pile shaft in cm^2	As = π D L	60083
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	54.97
12	FOS	Factor of safety	Generally 2.5	2.5

13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	22.0
End bearing capacity of pile				
$(Qu)_b$ = [Ap(1/2 D x □x N□+ P_d x N_q)] + [A_p x N_c x C_p] [Granular soil + Cohesive soil]				
1	D	Pile Dia in cms	Given	45
2	Ap	Cross Section area of base of pile in cm^2	Ap =$(\pi/4) D^2$	1590
3	□	Effective unit weight of soil at pile tip in kg/cm^3	Given	0.0021
4	Ø	Angle of internal friction around pile tip in degree	Given	23
5	N□	Bearing capacity factor based on Øat pile tip	$N_\gamma = 2 [e^{\pi \tan(\varphi)} * \tan^2(45+\varphi/2) + 1] * \tan(\varphi)$	8.20
6	Pd	Effective overburden pressure at pile tip kg/cm^2	Pd = $(Pdi)_{bottom}$	1.85
7	N_q	Bearing capacity factor based on Ø at pile tip	Refer Fig 2	7.4
8	N_c	Bearing capacity factor usually taken as 9	Nc is always 9.0 for deep foundation	9
9	C_p	Average cohesion at pile tip,kg/cm^2	Given	0.3
10	$(Q_u)_b$	Ultimate end bearing resistance, MT	$(Q_u)_b$ =[Ap x (0.5 x D x ϒ x $N_ϒ$ + Pd x Nq)] + [Ap x Nc x C_p]	26.72
11	FOS	Factor of safety	Generally 2.5	2.5
12	$(Q_s)_b$	Safe end bearing resistance in MT	$(Q_s)_b = (Q_u)_b$ / FOS	10.7
Qs = Safe capacity of pile in compression, MT			**Qs = $(Qs)_f + (Qs)_b$**	**54.5**
L = Total length of pile in M			**L = L1 +L2 +L3**	**9.8**

LOCATION 2

Layer 1				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Surat
1	D	Stem dia , cm	Given	60
2	L	Length of pile L1, cm	Given	100
3	Ap	C/S area of base of pile , cm^2	Ap =$(\pi/4) D^2$	2827
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top}$ + ϒ L	0.18
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.09
6	□	Unit weight in kg/cm^3	Given	0.0018
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.4
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	12
10	As	Surface area of pile shaft in cm^2	As = π D L	18850
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	7.90
12	FOS	Factor of safety	Generally 2.5	2.5
1	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	3.2

3				
Layer 2				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Surat
1	D	Stem dia , cm	Given	60
2	L	Length of pile L2, cm	Given	400
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	2827
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.18
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	0.92
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.55
6	□	Unit weight in kg/cm^3	Given	0.00185
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.32
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	19
10	As	Surface area of pile shaft in cm^2	As = π D L	75398
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	38.41
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	15.4
Layer 3				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Surat
1	D	Stem dia , cm	Given	60
2	L	Length of pile L3, cm	Given	350
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	2827
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.92
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	1.59
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	1.26
6	□	Unit weight in kg/cm^3	Given	0.0019
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.36
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	24
10	As	Surface area of pile shaft in cm^2	As = π D L	65973
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	60.64
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	24.3
End bearing capacity of pile				

$(Qu)_b$ = [Ap(1/2 D x □x N□+ P_d x N_q)] + [A_p x N_c x C_p] [Granular soil + Cohesive soil]				
1	D	Pile Dia in cms	Given	60
2	Ap	Cross Section area of base of pile in cm^2	Ap =(π/4) D^2	2827
3	□	Effective unit weight of soil at pile tip in kg/cm^3	Given	0.0021
4	Ø	Angle of internal friction around pile tip in degree	Given	24
5	N□	Bearing capacity factor based on Øat pile tip	$N_\gamma = 2 [e^{\pi \tan(\varphi)} * \tan^2(45+\varphi/2) + 1] * \tan(\varphi)$	9.44
6	Pd	Effective overburden pressure at pile tip kg/cm^2	Pd = $(Pdi)_{bottom}$	1.59
7	N_q	Bearing capacity factor based on Ø at pile tip	Refer Fig 2	8.5
8	N_c	Bearing capacity factor usually taken as 9	Nc is always 9.0 for deep foundation	9
9	C_p	Average cohesion at pile tip,kg/cm^2	Given	0.36
10	$(Q_u)_b$	Ultimate end bearing resistance, MT	$(Q_u)_b$ =[Ap x (0.5 x D x ϒ x $N_ϒ$ + Pd x Nq)] + [Ap x Nc x C_p]	49.28
11	FOS	Factor of safety	Generally 2.5	2.5
12	$(Q_s)_b$	Safe end bearing resistance in MT	$(Q_s)_b = (Q_u)_b$ / FOS	19.7
Qs = Safe capacity of pile in compression, MT			**Qs = $(Qs)_f + (Qs)_b$**	**62.5**
L = Total length of pile in M			**L = L1 +L2 +L3**	**8.5**

LOCATION 3

Layer 1				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Bharuch
1	D	Stem dia , cm	Given	75
2	L	Length of pile L1, cm	Given	250
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	4418
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top}$ + ϒ L	0.45
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.23
6	□	Unit weight in kg/cm^3	Given	0.0018
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.36
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	10
10	As	Surface area of pile shaft in cm^2	As = π D L	58905
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	23.56
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	9.4
Layer 2				

Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Bharuch
1	D	Stem dia , cm	Given	75
2	L	Length of pile L2, cm	Given	400
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	4418
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.45
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + ϒ L$	1.18
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.82
6	□	Unit weight in kg/cm^3	Given	0.00183
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.33
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	15
10	As	Surface area of pile shaft in cm^2	As = π D L	94248
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	51.77
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	20.7
Layer 3				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Bharuch
1	D	Stem dia , cm	Given	75
2	L	Length of pile L3, cm	Given	350
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	4418
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	1.18
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + ϒ L$	1.87
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	1.53
6	□	Unit weight in kg/cm^3	Given	0.0020
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.35
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	20
10	As	Surface area of pile shaft in cm^2	As = π D L	82467
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	74.66
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	29.9
End bearing capacity of pile				

$(Qu)_b$ = [Ap(1/2 D x □x $N_□$+ P_d x N_q)] + [A_p x N_c x C_p] [Granular soil + Cohesive soil]				
1	D	Pile Dia in cms	Given	75
2	Ap	Cross Section area of base of pile in cm^2	Ap =(π/4) D^2	4418
3	□	Effective unit weight of soil at pile tip in kg/cm^3	Given	0.0022
4	Ø	Angle of internal friction around pile tip in degree	Given	20
5	$N_□$	Bearing capacity factor based on Øat pile tip	$N_\gamma = 2 [e^{\pi \tan(\varphi)} * \tan^2(45+\varphi/2) + 1] * \tan(\varphi)$	5.39
6	Pd	Effective overburden pressure at pile tip kg/cm^2	Pd = $(Pdi)_{bottom}$	1.87
7	N_q	Bearing capacity factor based on Ø at pile tip	Refer Fig 2	4.8
8	N_c	Bearing capacity factor usually taken as 9	Nc is always 9.0 for deep foundation	9
9	C_p	Average cohesion at pile tip,kg/cm^2	Given	0.35
10	$(Q_u)_b$	Ultimate end bearing resistance, MT	$(Q_u)_b$ =[Ap x (0.5 x D x ϒ x $N_ϒ$ + Pd x Nq)] + [Ap x Nc x C_p]	55.63
11	FOS	Factor of safety	Generally 2.5	2.5
12	$(Q_s)_b$	Safe end bearing resistance in MT	$(Q_s)_b = (Q_u)_b$ / FOS	22.3
Qs = Safe capacity of pile in compression, MT			**Qs = $(Qs)_f + (Qs)_b$**	**82.2**
L = Total length of pile in M			**L = L1 +L2 +L3**	**10.0**

LOCATION 4

Layer 1				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location**
				Dahej
1	D	Stem dia , cm	Given	90
2	L	Length of pile L1, cm	Given	440
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	6362
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top}$ + ϒ L	0.80
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.40
6	□	Unit weight in kg/cm^3	Given	0.0018
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0.36
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	0
10	As	Surface area of pile shaft in cm^2	As = π D L	124407
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	44.79
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	17.9
Layer 2				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s]				**Location**

[Granular soil + Cohesive soil]				Dahej
1	D	Stem dia , cm	Given	90
2	L	Length of pile L2, cm	Given	360
3	Ap	C/S area of base of pile , cm^2	Ap $=(\pi/4) D^2$	6362
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.80
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	1.46
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	1.13
6	□	Unit weight in kg/cm^3	Given	0.00183
7	α	Reduction factor	Refer Fig 1	0.6
8	C	Average cohesion ,kg/cm^2	Given	0.81
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	0
10	As	Surface area of pile shaft in cm^2	As = π D L	101788
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	49.47
12	FOS	Factor of safety	Generally 2.5	2.5
13	$\mathbf{(Q_s)_f}$	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	19.8
Layer 3				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Dahej
1	D	Stem dia , cm	Given	90
2	L	Length of pile L3, cm	Given	600
3	Ap	C/S area of base of pile , cm^2	Ap $=(\pi/4) D^2$	6362
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	1.46
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	2.63
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	2.04
6	□	Unit weight in kg/cm^3	Given	0.0020
7	α	Reduction factor	Refer Fig 1	0.4
8	C	Average cohesion ,kg/cm^2	Given	1.1
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	0
10	As	Surface area of pile shaft in cm^2	As = π D L	169646
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	74.64
12	FOS	Factor of safety	Generally 2.5	2.5
13	$\mathbf{(Q_s)_f}$	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	29.9
End bearing capacity of pile				
$(Qu)_b$ = [Ap(1/2 D x □x $N_□$+ P_d x N_q)] + [A_p x N_c x C_p] [Granular soil + Cohesive soil]				
1	D	Pile Dia in cms	Given	90
2	Ap	Cross Section area of base of pile in cm^2	Ap $=(\pi/4) D^2$	6362
3	□	Effective unit weight of soil at pile tip in kg/cm^3	Given	0.0022

4	Ø	Angle of internal friction around pile tip in degree	Given	0
5	N□	Bearing capacity factor based on Øat pile tip	$N_\gamma = 2 [e^{\pi \tan(\varphi)} * \tan^2(45+\varphi/2) + 1] * \tan(\varphi)$	0.00
6	Pd	Effective overburden pressure at pile tip kg/cm^2	$Pd = (Pdi)_{bottom}$	2.63
7	N_q	Bearing capacity factor based on Ø at pile tip	Refer Fig 2	0.3
8	N_c	Bearing capacity factor usually taken as 9	Nc is always 9.0 for deep foundation	9
9	C_p	Average cohesion at pile tip,kg/cm^2	Given	1.1
10	$(Q_u)_b$	Ultimate end bearing resistance, MT	$(Q_u)_b$ =[Ap x (0.5 x D x ϒ x $N_ϒ$ + Pd x Nq)] + [Ap x Nc x C_p]	67.59
11	FOS	Factor of safety	Generally 2.5	2.5
12	$(Q_s)_b$	Safe end bearing resistance in MT	$(Q_s)_b = (Q_u)_b$ / FOS	27.0
Qs = Safe capacity of pile in compression, MT			**Qs = $(Qs)_f$ + $(Qs)_b$**	**94.6**
L = Total length of pile in M			**L = L1 +L2 +L3**	**14.0**

LOCATION 5

Layer 1				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Rajasthan
1	D	Stem dia , cm	Given	75
2	L	Length of pile L1, cm	Given	250
3	Ap	C/S area of base of pile , cm^2	Ap =$(\pi/4) D^2$	4418
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top}$ + ϒ L	0.45
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.23
6	□	Unit weight in kg/cm^3	Given	0.0018
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	21
10	As	Surface area of pile shaft in cm^2	As = π D L	58905
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	5.12
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	2.0
Layer 2				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Rajasthan
1	D	Stem dia , cm	Given	75
2	L	Length of pile L2, cm	Given	480
3	Ap	C/S area of base of pile , cm^2	Ap =$(\pi/4) D^2$	4418

4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	0.45
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	1.33
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	0.89
6	□	Unit weight in kg/cm^3	Given	0.00183
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	25
10	As	Surface area of pile shaft in cm^2	As = π D L	113097
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	47.03
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	18.8
Layer 3				
Frictional capacity of pile				
Ultimate frictional capacity $(Q_u)_f$ = [Σ K x Pdi x tan □ □x As] + [□ x C x A_s] [Granular soil + Cohesive soil]				**Location** Rajasthan
1	D	Stem dia , cm	Given	75
2	L	Length of pile L3, cm	Given	500
3	Ap	C/S area of base of pile , cm^2	Ap =(π/4) D^2	4418
4	K	Coefficient of earth pressure	K is taken as 1.0	1.0
5	Pdi	Top overburden pressure $(Pdi)_{top}$, kg/cm^2	$(Pdi)_{top}$ is always zero	1.33
		Bottom overburden pressure $(Pdi)_{bottom}$, kg/cm^2	$(Pdi)_{bottom} = (Pdi)_{top} + \Upsilon L$	2.31
		Average overburden pressure , kg/cm^2	Avg of $(Pdi)_{top}$& $(Pdi)_{bottom}$	1.82
6	□	Unit weight in kg/cm^3	Given	0.0020
7	α	Reduction factor	Refer Fig 1	1.0
8	C	Average cohesion ,kg/cm^2	Given	0
9	□ □ □ □ □	Angle of wall friction between pile and soil, degree	Given	32
10	As	Surface area of pile shaft in cm^2	As = π D L	117810
11	$(Q_u)_f$	Ultimate skin frictional resistance, MT	(Qu)f =[k x Pdi x tanδ x As] + [α x C x As]	133.86
12	FOS	Factor of safety	Generally 2.5	2.5
13	**$(Q_s)_f$**	Safe skin frictional resistance in MT	$(Q_s)_f = (Q_u)_f$ / FOS	53.5
End bearing capacity of pile				
$(Qu)_b$ = [Ap(1/2 D x □x $N_□$+ P_d x N_q)] + [A_p x N_c x C_p] [Granular soil + Cohesive soil]				
1	D	Pile Dia in cms	Given	75
2	Ap	Cross Section area of base of pile in cm^2	Ap =(π/4) D^2	4418
3	□	Effective unit weight of soil at pile tip in kg/cm^3	Given	0.0022
4	Ø	Angle of internal friction around pile tip in degree	Given	32
5	$N_□$	Bearing capacity factor based on Øat pile tip	$N_\gamma = 2 [e^{\pi \tan(\varphi)} * \tan^2(45+\varphi/2) + 1] * \tan(\varphi)$	30.21

6	Pd	Effective overburden pressure at pile tip kg/cm^2	Pd = $(Pdi)_{bottom}$	2.31
7	N_q	Bearing capacity factor based on Ø at pile tip	Refer Fig 2	29.0
8	N_c	Bearing capacity factor usually taken as 9	Nc is always 9.0 for deep foundation	9
9	C_p	Average cohesion at pile tip,kg/cm^2	Given	0
10	$(Q_u)_b$	Ultimate end bearing resistance, MT	$(Q_u)_b$ =[Ap x (0.5 x D x ϒ x $N_ϒ$ + Pd x Nq)] + [Ap x Nc x C_p]	306.44
11	FOS	Factor of safety	Generally 2.5	2.5
12	$(Q_s)_b$	Safe end bearing resistance in MT	$(Q_s)_b$ = $(Q_u)_b$ / FOS	122.6
Qs = Safe capacity of pile in compression, MT			**Qs = $(Qs)_f + (Qs)_b$**	**197.0**
L = Total length of pile in M			**L = L1 +L2 +L3**	**12.3**

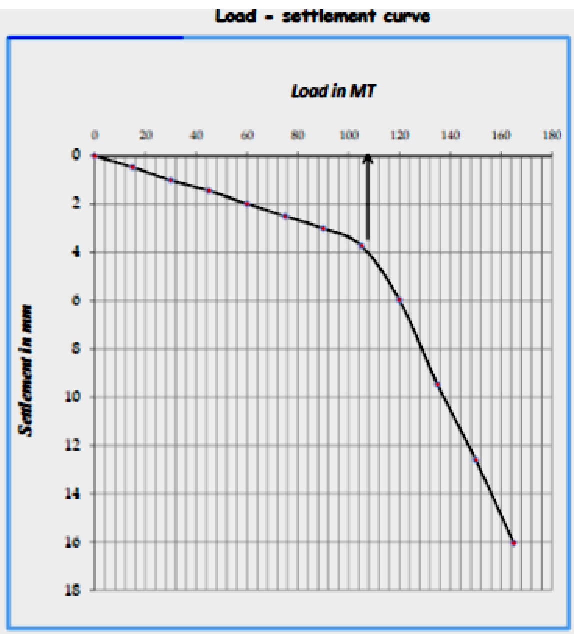
PILE LOAD TEST DATA:-

First of all pile load test equipment is set up at the actual field, having attached 3-4 deformation dial gauges. Suitable load increments are given at a definite interval of the time. Also the settlement due to loads is also recorded. Form this set of readings a graph of load v/s settlement is plotted.

Here pile load test data from actual site is given and is compared with our software.

LOCATION 1

	Load in MT	Dial Gauge Readings (L.C - 0.01 mm)				Average Reading	Settlement in mm
		A	B	C	D		
1	0	2500	2500	2500	2500	2500.00	0.00
2	15	2450	2456	2455	2453	2453.50	0.47
3	30	2401	2399	2395	2403	2399.50	1.01
4	45	2356	2356	2359	2354	2356.25	1.44
5	60	2301	2303	2302	2299	2301.25	1.99
6	75	2255	2253	2246	2249	2250.75	2.49
7	90	2200	2196	2203	2201	2200.00	3.00
8	105	2134	2125	2127	2126	2128.00	3.72
9	120	1903	1905	1893	1910	1902.75	5.97
10	135	1560	1556	1548	1549	1553.25	9.47
11	150	1240	1243	1234	1246	1240.75	12.59
12	165	896	895	891	901	895.75	16.04



Load, MT	Settlement, mm
0.0	0.00
15.0	0.47
30.0	1.01
45.0	1.44
60.0	1.99
75.0	2.49
90.0	3.00
105.0	3.72
120.0	5.97
135.0	9.47
150.0	12.59
165.0	16.04

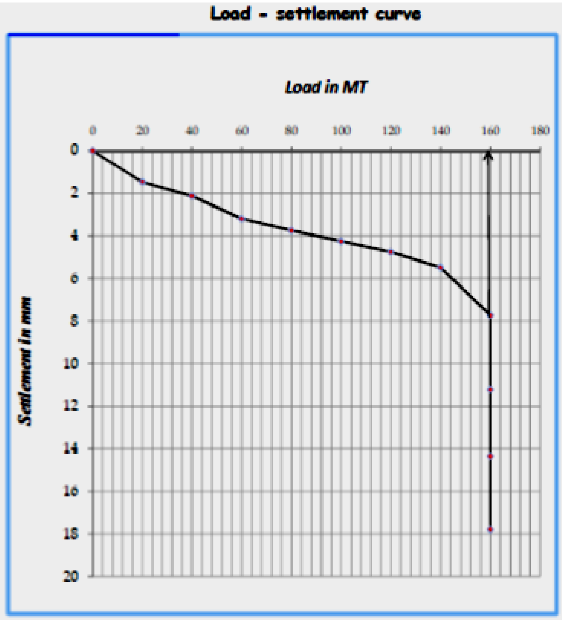
Safe pile capacity = Ultimate pile capacity /Factor of safety

= 114 / 2.5

= 56.4 MT

LOCATION 2

Sr. No.	Load in MT	Dial Gauge Readings (L.C - 0.01 mm)				Average Reading	Settlement in mm
		A	B	C	D		
1	0	3000	3000	3000	3000	3000.00	0.00
2	20	2900	2900	2930	2687	2854.25	1.46
3	40	2830	2800	2810	2713	2788.25	2.12
4	60	2856	2586	2693	2588	2680.75	3.19
5	80	2801	2533	2636	2533	2625.75	3.74
6	100	2755	2483	2580	2483	2575.25	4.25
7	120	2700	2426	2537	2435	2524.50	4.76
8	140	2634	2355	2461	2360	2452.50	5.48
9	160	2403	2135	2227	2144	2227.25	7.73
10	160	2060	1786	1882	1783	1877.75	11.22
11	160	1740	1473	1568	1480	1565.25	14.35
12	160	1396	1125	1225	1135	1220.25	17.80



Load, MT	Settlement, mm
0.0	0.00
20.0	1.46
40.0	2.12
60.0	3.19
80.0	3.74
100.0	4.25
120.0	4.76
140.0	5.48
160.0	7.73
160.0	11.22
160.0	14.35
160.0	17.80

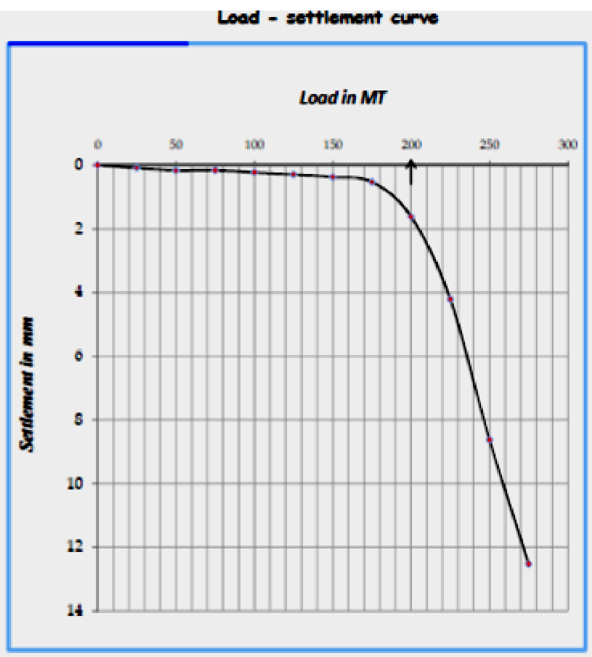
Safe pile capacity = Ultimate pile capacity /Factor of safety

= 160 / 2.5

= 64 MT

LOCATION 3

Sr. No.	Load in MT	Dial Gauge Readings (L.C - 0.01 mm)				Average Reading	Settlement in mm
		A	B	C	D		
1	0	3300	3300	3300	3300	3300	0.00
2	25	3290	3291	3295	3289	3291	0.09
3	50	3286	3285	3284	3279	3284	0.17
4	75	3281	3286	3285	3284	3284	0.16
5	100	3279	3280	3275	3274	3277	0.23
6	125	3270	3272	3276	3264	3271	0.30
7	150	3260	3270	3259	3261	3263	0.38
8	175	3247	3247	3247	3247	3247	0.53
9	200	3138	3137	3135	3141	3138	1.62
10	225	2877	2879	2884	2873	2878	4.22
11	250	2437	2430	2441	2439	2437	8.63
12	275	2047	2041	2054	2045	2047	12.53



Load, MT	Settlement, mm
0.0	0.00
25.0	0.09
50.0	0.17
75.0	0.16
100.0	0.23
125.0	0.30
150.0	0.38
175.0	0.53
200.0	1.62
225.0	4.22
250.0	8.63
275.0	12.53

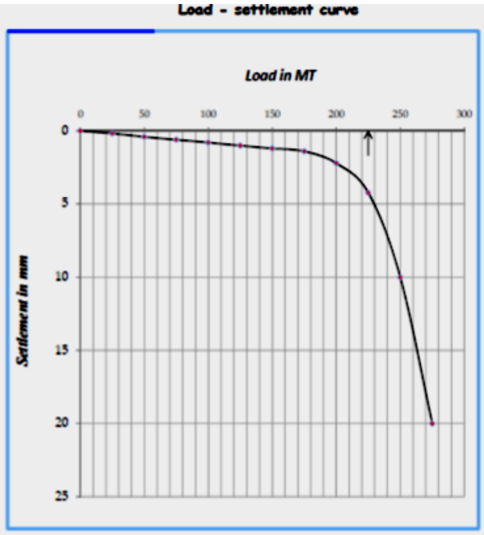
Safe pile capacity = Ultimate pile capacity /Factor of safety

= 200 / 2.5

= 80 MT

LOCATION 4

Sr. No.	Load in MT	Dial Gauge Readings (L.C - 0.01 mm)				Average Reading	Settlement in mm
		A	B	C	D		
1	0	4000	4000	4000	4000	4000	0.00
2	25	3980	3981	3994	3974	3982	0.18
3	50	3960	3964	3954	3959	3959	0.41
4	75	3942	3940	3936	3940	3940	0.61
5	100	3920	3925	3920	3916	3920	0.80
6	125	3902	3896	3900	3899	3899	1.01
7	150	3880	3880	3880	3880	3880	1.20
8	175	3860	3860	3860	3860	3860	1.40
9	200	3778	3779	3780	3779	3779	2.21
10	225	3786	3500	3522	3500	3577	4.23
11	250	3000	3002	3000	2996	3000	10.01
12	275	1996	2006	2000	1995	1999	20.01

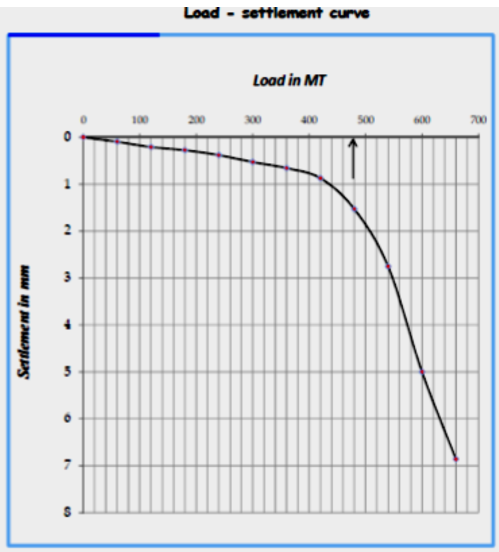


Load, MT	Settlement, mm
0.0	0.00
25.0	0.18
50.0	0.41
75.0	0.61
100.0	0.80
125.0	1.01
150.0	1.20
175.0	1.40
200.0	2.21
225.0	4.23
250.0	10.01
275.0	20.01

Safe pile capacity = Ultimate pile capacity /Factor of safety
= 230 / 2.5
= 92 MT

LOCATION 5

Sr. No.	Load in MT	Dial Gauge Readings (L.C - 0.01 mm)				Average Reading	Settlement in mm
		A	B	C	D		
1	0	3310	3310	3310	3310	3310.00	0.00
2	60	3301	3299	3300	3302	3300.50	0.10
3	120	3286	3289	3290	3291	3289.00	0.21
4	180	3280	3281	3283	3286	3282.50	0.28
5	240	3273	3271	3275	3269	3272.00	0.38
6	300	3255	3256	3258	3260	3257.25	0.53
7	360	3242	3240	3245	3250	3244.25	0.66
8	420	3226	3224	3219	3222	3222.75	0.87
9	480	3157	3157	3157	3157	3157.00	1.53
10	540	3106	3010	3012	3010	3034.50	2.76
11	600	2810	2810	2810	2810	2810.00	5.00
12	660	2624	2621	2629	2622	2624.00	6.86



Load, MT	Settlement, mm
0.0	0.00
60.0	0.10
120.0	0.21
180.0	0.28
240.0	0.38
300.0	0.53
360.0	0.66
420.0	0.87
480.0	1.53
540.0	2.76
600.0	5.00
660.0	6.86

Safe pile capacity = Ultimate pile capacity /Factor of safety
= 480 / 2.5
= 192 MT

COMPARISION OF RESULTS

We have collect the five numbers of pile load test data, which is sufficient to verify the accuracy of the software. By comparison of the actual field pile load test results are precisely same to the software results. Following table shows the comparison of the calculated results of the pile load test by the manually and by the software.

Sr no.	**Field pile capacity(MT)**	**Calculated capacity in software(MT)**
1	56.5	56.4
2	62.2	64
3	82.2	80
4	94.6	92
5	197	192

Conclusions and future scope:-

On the basis of software we develop we conclude that pile capacity of soil calculated by software is precisely same as from pile load test. However necessary updates/modifications in the software should be incorporated time to time with any amendment in the IS code, new concepts and other modifications in the literature based on experimental results.

The software we are making can be used "n" number of times according to the changes in the IS codal provisions and any literature changes can be incorporated.

The software can be used for finding out the pile load capacity in case of different soil stratification and variable length of piles.

FORMULA

The given formula is derived from the IS CODE 2911.

a) Frictional capacity of pile:

(Qu)f = [ΣK x Pdi x tand x As] + [a x C x As]

[Granular soil + Cohesive soil]

b) End bearing capacity of pile:

(Qu)b = [Ap(1/2 D x g x Ng + Pd x Nq)] + [Ap x Nc x Cp]

[Granular soil + Cohesive soil]

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